EIC SOFTWARE CONSORTIUM

Update in EIC Generic Detector R&D meeting on January 30, 2020

ESC and the EIC User Group

Charge The **EICUG Software Working Group**'s initial focus will be on simulations of physics processes and detector response to enable quantitative assessment of measurement capabilities and their physics impact. (…) The working group will build on the considerable progress made within the **EIC Software Consortium** and other efforts.

53 members

Growing core group

ESC
EIC SOFTWARE CONSORTIUM


M. Asai (SLAC)


N. Brei (JLAB)


A. Bressan (Trieste)


W. Deconinck (Manitoba)


M. Diefenthaler (JLAB)


J. Furletova (JLAB)


S. Joosten (ANL)


K. Kauder (BNL)


A. Kiselev (BNL)


D. Lawrence (JLAB)


C. Pinkenburg (BNL)


M. Potekhin (BNL)


D. Romanov (JLAB)


T. Wenaus (BNL)

Role of Software Working Group

Develop

Support

Workflow environment for EIC simulations

- **to use** (tools, documentation, support) **and**
- **to grow with user input** (direction, documentation, tools)

Involvement from EICUG

e.g. benchmark processes, detector designs, reconstructions algorithms

Introduction

Getting started

Point of entry

HOME | JOIN EICUG | SCIENCE | ORGANIZATION | PHONEBOOK | CALENDAR | SOFTWARE | DOCUMENTS | MEDIA | LOGIN

Home » EIC Software

EIC Software

Software Working Group

The EICUG has formed a Software Working Group that collaborates with EIC Software initiatives and other experts in NP and HEP on detector and physics simulations for the EIC. The short-term goal of the working group is to meet in FY20 the requirements for common tools and documentation in the EICUG. The current work focusses on a common Geant4 infrastructure for the EIC that allows geometry exchange between the eRHIC and JLEIC concepts.

JupyterLab

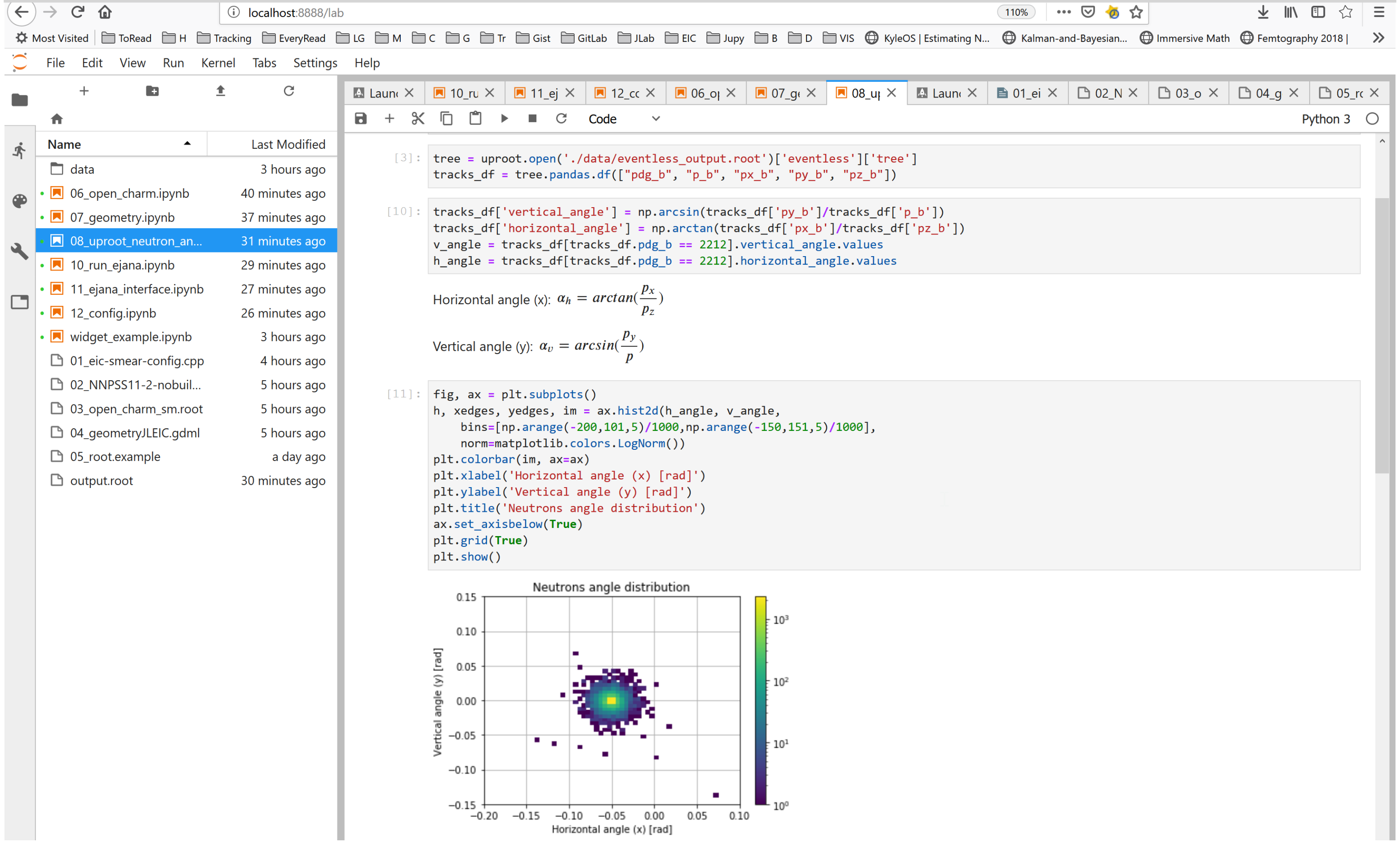
The Software Working Group has adapted JupyterLab as a collaborative workspace to further develop EIC Science, to examine detector requirements, and to work on detector designs and concepts. JupyterLab is a web-based interactive analysis environment to create and share documents that contain the analysis code, the narrative of the analysis including graphics and equations, and visualizations of the analysis results. This will allow the EICUG not only to pursue simulations in a manner that is accessible, consistent, and reproducible to the EICUG as a whole, but also to build a collection of analyses and analysis tools in the fully extensible and modular JupyterLab environment. A quick start tutorial for fast simulations is available on the website for EIC Software.

Important links

Mailing list	eicug-software@eicug.org (subscribe via Google Group)
Repository	http://gitlab.com/eic
Website	https://software.eicug.org

Collaborative workspace for EIC simulations

JupyterLab
- web-based interactive analysis environment

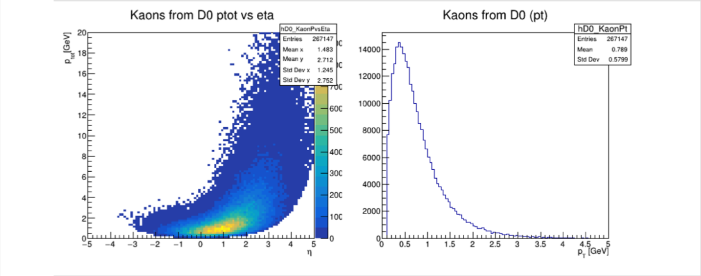


Jupyter Notebooks
- writing analysis code

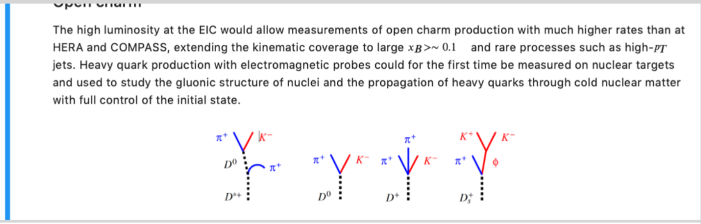
Python

Root/C++

- visualization of results

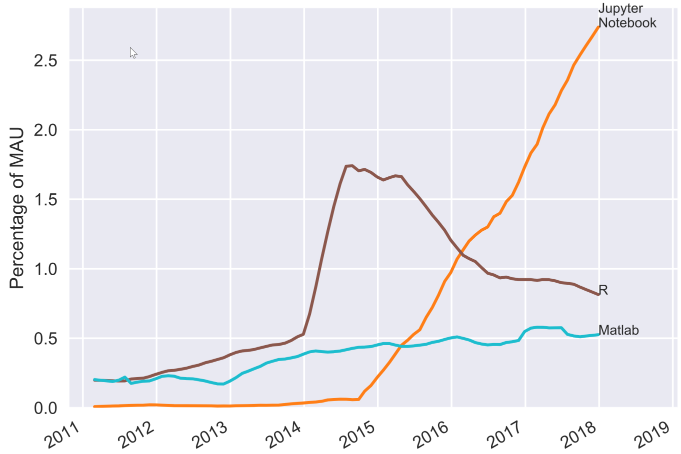


- narrative of the analysis



JupyterLab environment

- **bridge to modern data science**, e.g.,



  - *Nature* **563**, 145-146 (2018): “Why Jupyter is data scientists’ computational notebook of choice”
  - more than three million Jupyter Notebooks publicly available on GitHub

- **collaborative workspace** to create and share Jupyter Notebooks

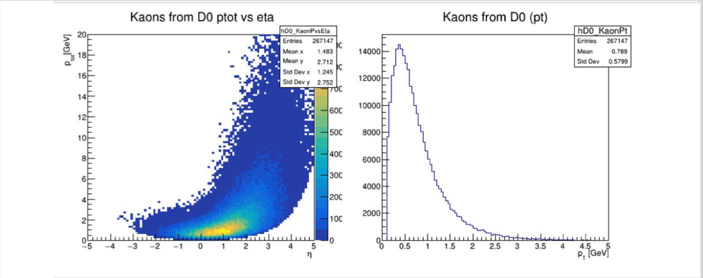
- **web-based interactive analysis environment** accessible, consistent, reproducible analyses

- **fully extensible and modular** build a collection of analyses and analysis tools

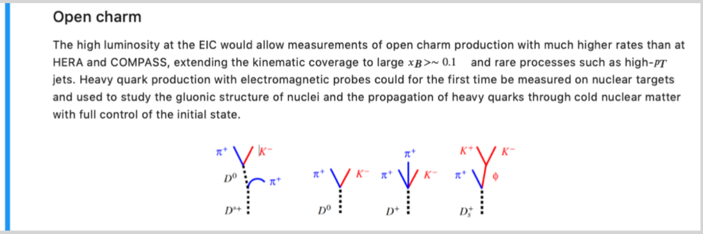
Jupyter Notebooks

- writing analysis code

- visualization of results



- narrative of the analysis



Modular design

Escaping complexity scaling trap

- provide interfaces to internal layers
- interaction between layers must be clear

Modularity each layer must be replaceable

simple	JupyterLab web interface
moderate	analysis scripts, python
complex	eJANA, plugins, C++
expert	JANA, eic-smear, *fun4all*, ROOT, Geant4

../data/beagle_eD.txt

[3]:
```
jana.run()
```

Total events processed: 10001 (~ 10.0 kevt)

▸ **Full log**

▾ **Run command**

ejana

-Pplugins=beagle_reader,vmeson,event_writer

-Pnthreads=1

-Pnevents=10000

-Poutput=beagle.root

../data/beagle_eD.txt

-Pjana:debug_plugin_loading=1

EIC Software

Simulation of physics processes

Monte Carlo Event Generators
Tutorials in preparation

Simulation of detector responses

Fast simulations
Tutorials ✓

Full simulations
Tutorials ✓

Physics analysis

Reconstruction of physics processes
Tutorials in preparation

Remote tutorials

Jan. 9 — **Introduction** fast simulations, JupyterLab analysis 9:00 a.m. and 6:00 p.m. (EDT) with **79 participants** — **recording**

recorded

Jan. 29 — **Detector Full Simulations** integrate subdetector in existing detector concepts, modify detector concept with with **68 participants**

Feb. 6 — **Detector Full Simulations** repetition of **Jan. 29**

Continuing tutorials according to survey and other requests

Feb. — **MCEG, reconstruction** — **stay tuned**

January 2020

Su	Mo	Tu	We	Th	Fr	Sa
			1	2	3	4
5	6	7	8	**9**	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	**29**	**30***	**31***	

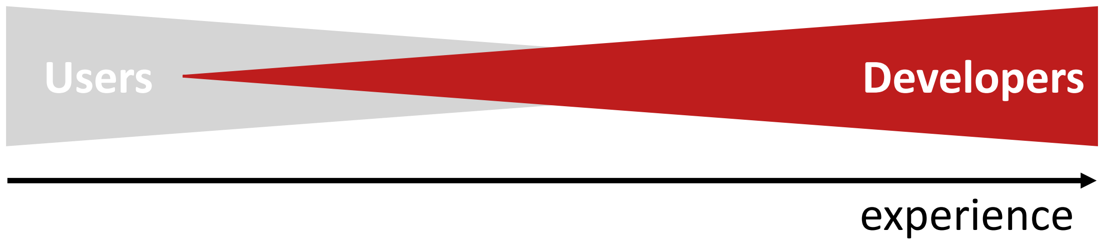
February 2020

Su	Mo	Tu	We	Th	Fr	Sa
						1
2	3	4	5	**6**	7	8

Support

support team

being built up
weekly shifts



software-support@eicug.org

Mailing list (anyone can contact)
Google forum (for archive of support requests and start of knowledge base)

http://eicug.slack.com/

EICUG Slack workspace with software-support channel

Section

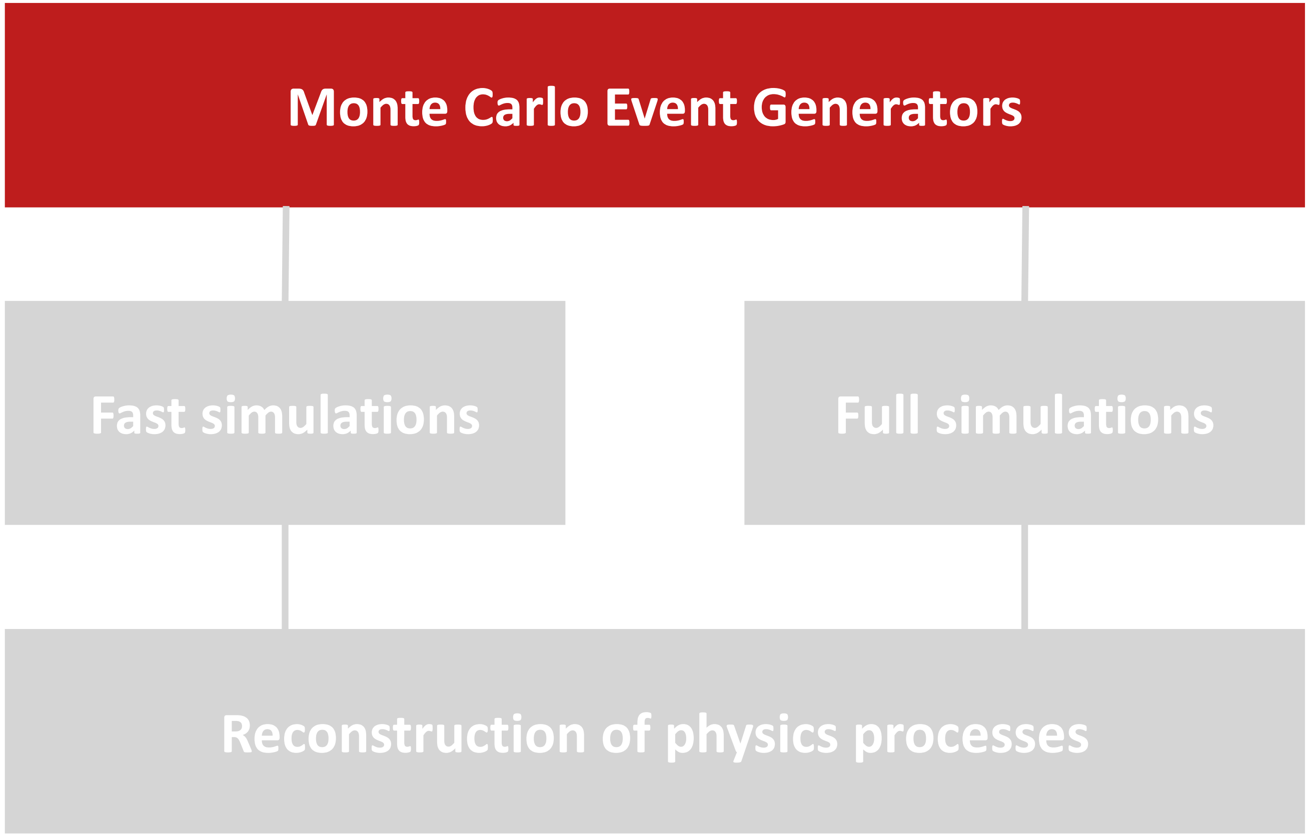
Status of EICUG simulations

Simulations of physics processes and detector responses

Simulation of physics processes

Simulation of detector responses

Physics analysis



Broad collection of event generators used for EIC

Monte Carlo Event Generators (MCEG)

The following event generators are available:

- ep
  - DJANGOH: (un)polarised DIS generator with QED and QCD radiative effects for NC and CC events.
  - gmc_trans: A generator for semi-inclusive DIS with transverse-spin- and transverse-momentum-dependent distributions.
  - LEPTO: A leptoproduction generator - used as a basis for PEPSI and DJANGOH
  - LEPTO-PHI: A version of LEPTO with "Cahn effect" (azimuthal asymmetry) implemented
  - MILOU: A generator for deeply virtual Compton scattering (DVCS), the Bethe-Heitler process and their interference.
  - PYTHIA: A general-purpose high energy physics event generator.
  - PEPSI: A generator for polarised leptoproduction.
  - RAPGAP: A generator for deeply inelastic scattering (DIS) and diffractive $e + p$ events.
- eA
  - BeAGLE: Benchmark eA Generator for LEptoproduction - UNDER CONSTRUCTION - a generator to simulate ep/eA DIS events including nuclear shadowing effects (based on DPMJetHybrid)
  - DPMJet: a generator for very low Q2/real photon physics in eA
  - DPMJetHybrid: a generator to simulate ep/eA DIS events by employing PYTHIA in DPMJet
  - Sartre is an event generator for exclusive diffractive vector meson production and DVCS in ep and eA collisions based on the dipole model.

From https://wiki.bnl.gov/eic/index.php/Simulations and available in https://gitlab.com/eic/mceg

JupyterLab integration of MCEG (ongoing)

Example: Container for Pythia8+DIRE

jupyter README✔ 8 minutes ago Logout

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```
Welcome to the Jupyter notebooks for Pythia 8 and DIRE!


You have the choice to run the following notebooks:

pythiaPI.ipynb
  Gives a basic idea of the Pythia 8 event generator, by using the Python
  interface of Pythia 8. You can adjust a set of parameters and choose
  from different different histograms to be plotted.

pythiaRivetPI.ipynb
  Shows how to use the Pythia 8 event generator, together with Rivet,
  by using the Python interface of Pythia 8.

pythiaRivet.ipynb
  Shows how to use Pythia 8, together with Rivet, by using an already
  compiled executable called pythiaHepMC. You can adjust a set of parameters
  and a settings file is created.

pythiaRivetUS.ipynb
  As pythiaRivet.ipynb, but uses a prepared settings file, to be provided
  by the user.

direRivet.ipynb
  Shows how to use Pythia 8 with the DIRE parton shower, together with
  Rivet, by using the default DIRE executable. You can adjust a set of
  parameters and a settings file is created.

direRivetUS.ipynb
  As direRivet.ipynb, but uses a prepared settings file, to be provided
  by the user.

direEvent.ipynb
  Pythia 8 with the DIRE parton shower, graphical output of one event
  with the default DIRE exectuable.
  The process can be choosen as well as a few basic parameters.

tuning.ipynb
  Tuning with Professor, Rivet, and Pythia 8 / DIRE.
```

Jupyter notebook interface

Pythia 8 standalone

This notebook gives a basic idea of the Pythia 8 event generator, by using the Python interface of Pythia 8. You can adjust a set of parameters and choose from different different histograms to be plotted.

First, lets import all neccessary modules.

In [1]:
```
import os, sys, pythia8
from plotting import MULTIHIST
import py8settings as py8s
```

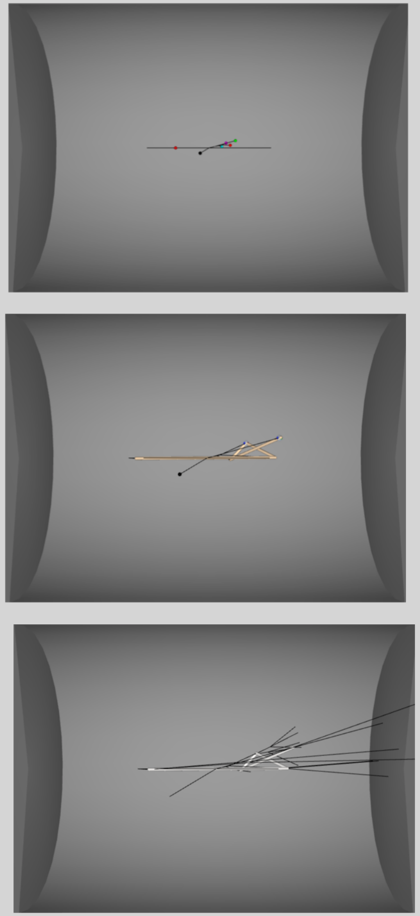
Now we create a Pythia 8 object and apply the settings to define the incoming beams. More settings can be adjusted later.

In [2]:
```
# Setup pythia, apply beam settings.
pythia = pythia8.Pythia()
py8s.beam_settings(pythia)
```

You can now set the parameters for the incoming beams:

beam A id [Beams:idA]	e-
beam B id [Beams:idB]	p
beam frame type [Beams:frameType]	2: back-to-back beams with different energies, set Beams:eA and Beams:eB
CMS energy for Beams:frameType = 1 [Beams:eCM]	65.7
beam A energy for Beams:frameType = 2 [Beams:eA]	10.8
beam B energy for Beams:frameType = 2 [Beams:eB]	100

Visualization of ep collision



MCEG R&D for EIC

Unique MCEG requirements for EIC Science

- MCEG for polarized ep, ed, and eHe^3
    - including novel QCD phenomena: GPDs, TMDs
- MCEG for eA

MCEG community

- focus of last two decades: **LHC**
    - **lesson learned** high-precision QCD measurements require high-precision MCEGs
    - MCEG not about tuning but about physics
- ready to work on ep/eA

MCEG R&D for EIC

General-purpose MCEGs, HERWIG, PYTHIA, and SHERPA, will be significantly improved w.r.t. MCEGs at HERA time:

- MCEG-data comparisons in Rivet will be critical to tune the MCEGs to DIS data and theory predictions.
- The existing general-purpose MCEG should soon be able to simulate NC and CC unpolarized observables also for eA. A precise treatment of the nucleus and, e.g., its breakup is needed.
- First parton showers and hadronization models for ep with spin effects, but far more work needed for polarized ep / eA simulations.
- Need to clarify the details about merging QED+QCD effects (in particular for eA).

MCEG for eA

- **pioneering projects BeAGLE** (eRD17), spectator tagging in ed, Sartre
- **active development** eA adaptation of JETSCAPE, Mueller dipole formalism in Pythia8 (ala DIPSY)

TMD physics

- Vibrant community working on various computational tools for TMDs.
- CASCADE: MCEG for unpolarized TMDs (unintegrated TMDs) at high energy.
- Need more verification of MCEG models with TMD theory / phenomenology.

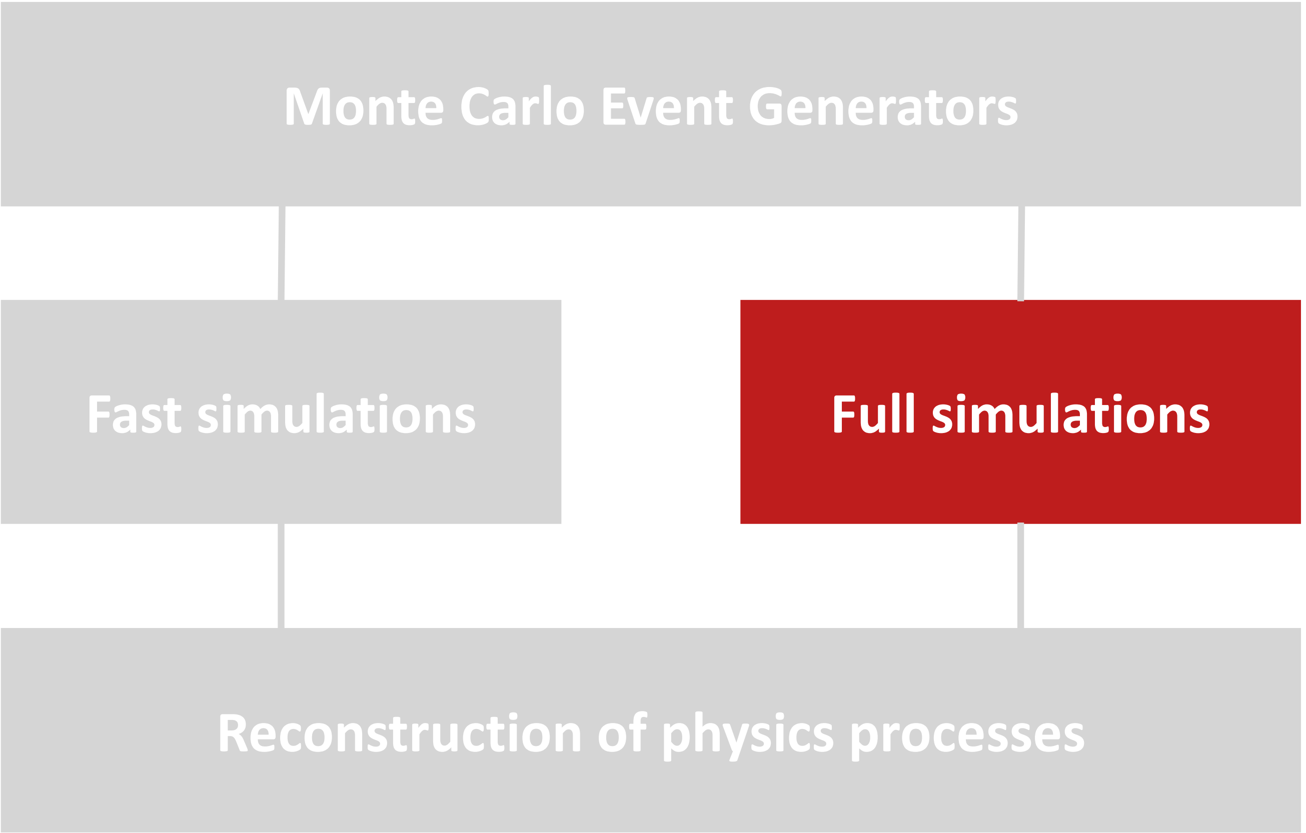
MCEG for ep We are on a very good path, but still quite some work ahead.
MCEG for eA Less clear situation about theory and MCEG.

Simulations of physics processes and detector responses

Simulation of physics processes

Simulation of detector responses

Physics analysis



Detector Simulation

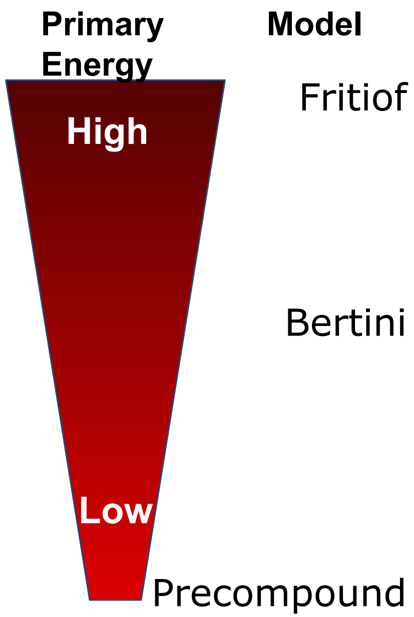
- **collaboration with Geant4 International Collaboration**
  - **liaison** Makoto Asai (SLAC)
- **Geant4 for EIC**
  - coordinate input for Geant4 validation based on EIC physics list maintained by (former) SLAC Geant4 group
  - Geant4 10.6 recommended (released Dec. 6)

09/24 Geant4 Technical Forum on EIC

- EIC detector and physics simulations rely on Geant4
- knowledge transfer (e.g., sub-event parallelism or tessellated solids)
- maintain EIC physics lists
- **request** improved photo-nuclear and electro-nuclear reactions

EIC

- energy range is different from LHC
- validation, tuning and extension including test beam studies



Geant4 infrastructure for EICUG

Requirements

- **EIC Generic Detector R&D program (T. Ullrich)** *“a simple lite setup with a well defined geometry description standard that is easy to use”*
- **EICUG** Flexible accelerator and detector interface with full support of existing IR designs and detector concepts

Approach

- common repository for detector R&D for EIC
- common detector description in Geant4 (C++) and not yet DD4hep (sub-detectors developed in Geant4 (C++))
- common detector naming convention for EIC
- possible common hits output structure
- concise document and template on how to implement and integrate subdetector in EIC detector concepts

Discussion

- **two in-person meetings**
  - 07/10 EIC Software Meeting at BNL (minutes)
  - 09/24 EIC Software Meeting at JLAB (minutes)
- **evaluation** 09/30, 10/21, 10/28, 11/18, 11/25

Two solutions proposed

1. detector simulations in **fun4all**, major update for common EIC simulations
2. Geant4 application **g4e**, integrated in JupyterLab

Why two options?

- At The Software Working Group was caught by the start of the “Yellow Report” effort with two ongoing developments for full simulations:
  - **fun4all**, originated from within (s)PHENIX, mature and centered around the use of ROOT macros
  - **g4e**, build up for the EIC (and therefore in a “younger” stage of development) constructed as a pure GEANT4 application (and integrated into JupyterLab environment)
- Each of the two is supported by a core team of developers.
- We put forward both options, leaving the “users” the freedom to choose base on their coding preferences.
- We will take advantage of the two codes to cross-check few selected and critical results in order to improve our confidence in the outcome of the simulations.

EIC Software Meeting on January 29

EIC Software Tutorial on Full Detector Simulation

Wednesday Jan 29, 2020, 9:00 AM → 9:00 PM US/Eastern

Large Seminar Room (BNL Physics)

Andrea Bressan (Trieste), Markus Diefenthaler (Jefferson Lab), Torre Wenaus (BNL)

Detector Full Simulation Tutorial

- integrate subdetector in existing detector concepts
- using Jaroslav Adam's luminosity monitor (Geant4 C++) as example
- modify detector concept

9:00 AM → 10:00 AM **Introduction, Common aspects** — Large Seminar Room

- 9:00 AM **Introduction and common aspects** — 20m
  Speaker: Markus Diefenthaler (Jefferson Lab)
  Diefenthaler-EICUG...
- 9:20 AM **Geant4 for the EIC luminosity monitor** — 20m
  Example Geant4 full simulation use case
  Speaker: Jaroslav Adam (BNL)
  JA-Lumi_software_...

10:00 AM → 12:00 PM **Fun4All simulation details** — Large Seminar Room

You will need an racf account or the capability to run singularity containers. To install the singularity container on your laptop/desktop please follow these instructions:
https://github.com/EIC-Detector/Singularity
You will need to type a few commands, here is a web page from where you can cut and paste them:
https://www.phenix.bnl.gov/WWW/publish/phnxbld/EIC/tutorial/

Convener: Chris Pinkenburg (BNL)

EIC-simulation-tuto... EIC-simulation-tuto...

12:00 PM → 2:00 PM **Lunch** — 2h — Large Seminar Room

2:00 PM → 4:00 PM **g4e simulation details** — Large Seminar Room

Pull:
docker pull electronioncollider/epic-gui

Run:
docker run --rm -it -p 8888:8888 -p 6080:6080 electronioncollider/epic-gui

Full (enables debugging C++ code in docker and attaching your own VNC viewer)
docker run -it --rm -p8888:8888 -p 6080:6080 -p 5901:5901 --cap-add=SYS_PTRACE --security-opt seccomp=unconfined electronioncollider/epic-gui

Convener: Dmitry Romanov (Jefferson lab)

2020-01 Full simul...

4:00 PM → 6:00 PM **Discussion of future 'greenfield' simulation/framework** — Large Seminar Room

Greenfield as in a community-wide project on greenfield simulation toolkit/framework freeing us from the legacy of existing options while leveraging everyone's experience (greenfield isn't the planned name of the software)

Conveners: Andrea Bressan (INFN), Markus Diefenthaler (Jefferson Lab), Torre Wenaus (BNL)

Diefenthaler - EIC - ...

Greenfield simulation(framework)

Motivation

- community-wide project on **event-processing software** freeing us from the legacy of existing options while leveraging everyone's experience

Definition

- **Greenfield event-processing software** := community-wide project on event-processing software freeing us from the legacy of existing options while leveraging everyone's experience. The project will define requirements and build up the event-processing software on these requirements. Input by the wider scientific and software & computing communities is encouraged.

Approach

1. Define **requirements** and write them down.
2. **Study** existing implementations and **consult** with wider scientific community and software developers.
3. **Agree** on design.
4. **Implement** our design.

Accelerator interface

Accelerator design (beam elements)

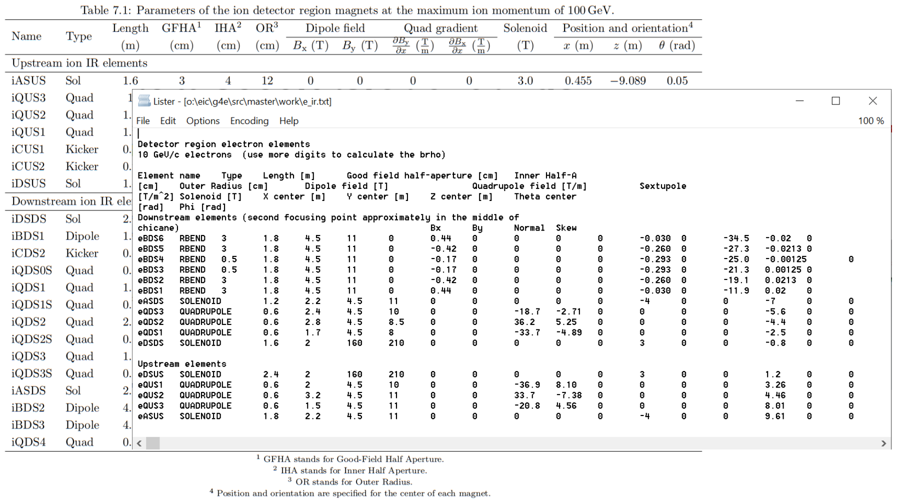


Table 7.1: Parameters of the ion detector region magnets at the maximum ion momentum of 100 GeV.

Name	Type	Length (m)	GFHA[1] (cm)	IHA[2] (cm)	OR[3] (cm)	Dipole field B_x (T)	Dipole field B_y (T)	Quad gradient $\frac{\partial B_y}{\partial x}$ ($\frac{T}{m}$)	Quad gradient $\frac{\partial B_x}{\partial x}$ ($\frac{T}{m}$)	Solenoid (T)	Position and orientation[4] x (m)	z (m)	θ (rad)
Upstream ion IR elements													
iASUS	Sol	1.6	3	4	12	0	0	0	0	3.0	0.455	−9.089	0.05
iQUS3	Quad	1											
iQUS2	Quad	1.											
iQUS1	Quad	1.											
iCUS1	Kicker	0.											
iCUS2	Kicker	0.											
iDSUS	Sol	1.											
Downstream ion IR ele													
iDSDS	Sol	2.											
iBDS1	Dipole	1.											
iCDS2	Kicker	0.											
iQDS0S	Quad	0.											
iQDS1	Quad	1.											
iQDS1S	Quad	0.											
iQDS2	Quad	2.											
iQDS2S	Quad	0.											
iQDS3	Quad	1.											
iQDS3S	Quad	0.											
iASDS	Sol	2.											
iBDS2	Dipole	4.											
iBDS3	Dipole	4.											
iQDS4	Quad	0.											

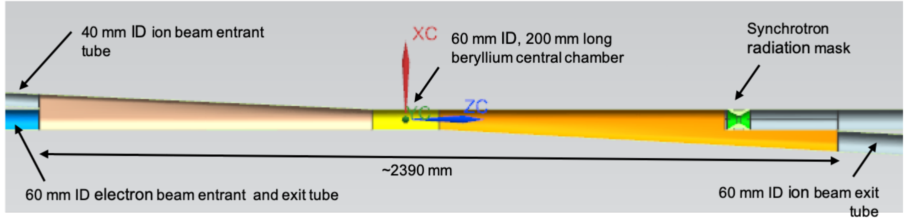
Lister - [o:\eic\g4e\src\master\work\e_ir.txt]

File Edit Options Encoding Help 100 %

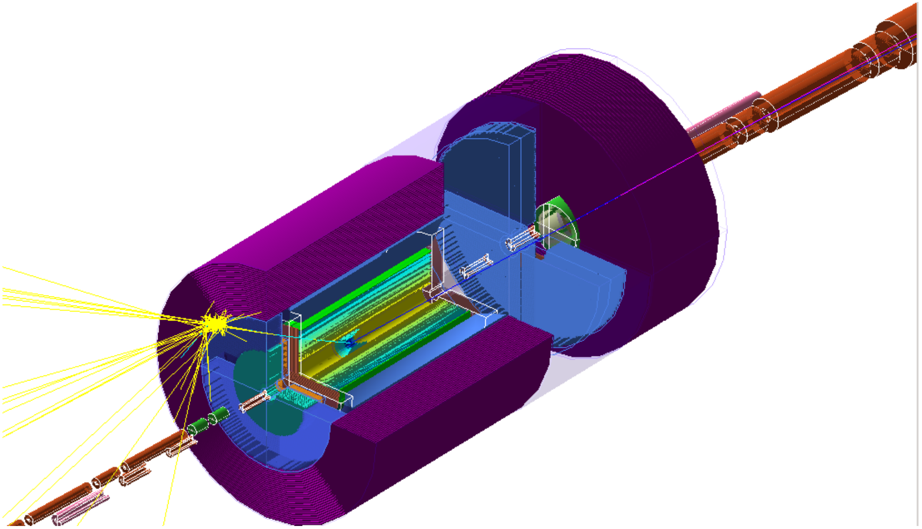
```
Detector region electron elements
10 GeV/c electrons  (use more digits to calculate the brho)

Element name    Type    Length [m]      Good field half-aperture [cm]   Inner Half-A
[cm]    Outer Radius [cm]       Dipole field [T]                Quadrupole field [T/m]          Sextupole
[T/m^2] Solenoid [T]    X center [m]    Y center [m]    Z center [m]    Theta center
[rad]   Phi [rad]
Downstream elements (second focusing point approximately in the middle of
chicane)                                        Bx      By      Normal  Skew
eBDS6   RBEND   3       1.8     4.5     11      0       0.44    0       0       0       0       -0.030  0       -34.5   -0.02   0
eBDS5   RBEND   3       1.8     4.5     11      0       -0.42   0       0       0       0       -0.260  0       -27.3   -0.0213 0
eBDS4   RBEND   0.5     1.8     4.5     11      0       -0.17   0       0       0       0       -0.293  0       -25.0   -0.00125        0
eBDS3   RBEND   0.5     1.8     4.5     11      0       -0.17   0       0       0       0       -0.293  0       -21.3   0.00125 0
eBDS2   RBEND   3       1.8     4.5     11      0       -0.42   0       0       0       0       -0.260  0       -19.1   0.0213  0
eBDS1   RBEND   3       1.8     4.5     11      0       0.44    0       0       0       0       -0.030  0       -11.9   0.02    0
eASDS   SOLENOID        1.2     2.2     4.5     11      0       0       0       0       0       -4      0       0       -7      0       0
eQDS3   QUADRUPOLE      0.6     2.4     4.5     10      0       0       -18.7   -2.71   0       0       0       0       -5.6    0       0
eQDS2   QUADRUPOLE      0.6     2.8     4.5     8.5     0       0       36.2    5.25    0       0       0       0       -4.4    0       0
eQDS1   QUADRUPOLE      0.6     1.7     4.5     8       0       0       -33.7   -4.89   0       0       0       0       -2.5    0       0
eDSDS   SOLENOID        1.6     2       160     210     0       0       0       0       0       3       0       0       -0.8    0       0

Upstream elements
eDSUS   SOLENOID        2.4     2       160     210     0       0       0       0       0       3       0       0       1.2     0       0
eQUS1   QUADRUPOLE      0.6     2       4.5     10      0       0       -36.9   8.10    0       0       0       0       3.26    0       0
eQUS2   QUADRUPOLE      0.6     3.2     4.5     11      0       0       33.7    -7.38   0       0       0       0       4.46    0       0
eQUS3   QUADRUPOLE      0.6     1.5     4.5     11      0       0       -20.8   4.56    0       0       0       0       8.01    0       0
eASUS   SOLENOID        1.8     2.2     4.5     11      0       0       0       0       0       -4      0       0       9.61    0       0
```

[1] GFHA stands for Good-Field Half Aperture.
[2] IHA stands for Inner Half Aperture.
[3] OR stands for Outer Radius.
[4] Position and orientation are specified for the center of each magnet.

Engineering Design (CAD)



Detector Simulations (Geant4)



Tuning

Status

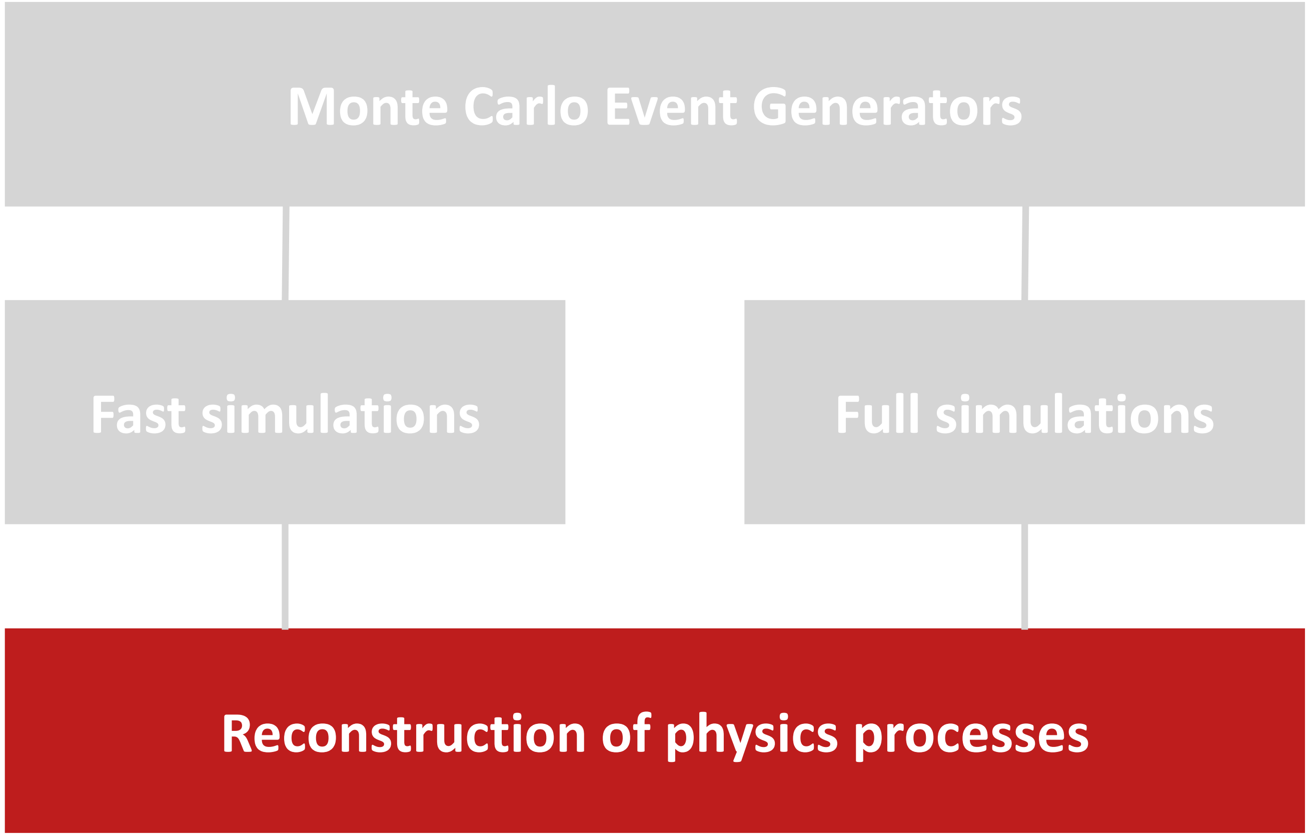
eRHIC and JLEIC information available
Common interface under active development

Simulations of physics processes and detector responses

Simulation of physics processes

Simulation of detector responses

Physics analysis



Reconstruction options (in alphabetical order)

A Common Tracking Software (ACTS)

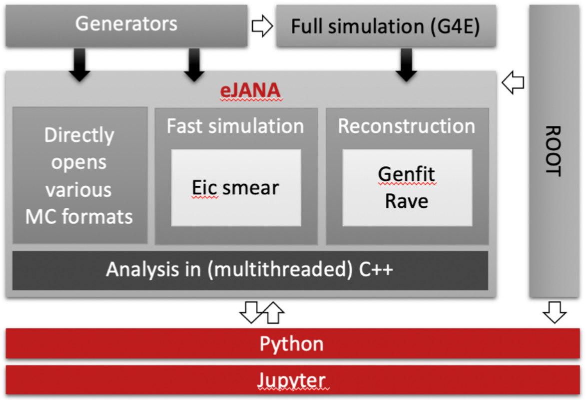
ATLAS software → generic, framework- and experiment-independent track reconstruction software

Collaboration of LBNL NP and HEP (Y. S. Lai et al.) for ACTS for EIC

EiCRoot (part of yesterday's tutorial)

eJANA (community reference reconstruction)

ESC project
Modular reconstruction based on EIC tracking tools (ANL, BNL, JLAB)
Prototype based on JANA2 + plugins for GENFIT and RAVE



Fun4all (part of yesterday's tutorial)

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Workflow environment for EICUG

- **fast and full simulation** available and being extended with community input
- **documentation** started and being improved with community input
- **Support** being built up

Grow with user input

- excited to support EIC Physics and Detector Conceptual Development / Yellow Report

Next steps

- excited to support EIC TDR
- rely for now on eRD20 funding

ESC

EIC SOFTWARE CONSORTIUM